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Vulcanite Pamphlet No. 6

Selection and Proportion of Aggregates for Concrete

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Economical Selection and Proportion of Aggregates for Portland Cement Concrete

By ALBERT MOYER

ASSOC. AM. SOC. C. E.

THE object of this article is to give a practical method which will enable any concrete constructor to make economical use of the best aggregates, so proportioning them as to give the maximum strength and density with a minimum amount of cement. Concrete under discussion is plain and not reinforced, for reinforced concrete, an over-cemented mixture is sometimes necessary, particularly in column construction.

There is a theory that the strength of concrete depends entirely on the adhesion of the cement to the sand and stone. The writer cannot see any tangible reason for this theory as applied to compression strength, for which concrete is designed. Eliminating tensile strength from the mind, it would be possible to make a concrete with a hardening non-cementing material, which could be poured in between the particles of sand and stone so as to fill the voids. While this material would not adhere to the sand or stone, it binds around each particle and thus not only furnishes an arch action, but by its own strength keeps the mass from spreading. Portland Cement not only binds around, but also adheres to each particle of the aggregate. Therefore maximum density is maximum strength in a well balanced concrete of the best materials.

The ideal or theoretically perfect concrete is that in which the best aggregates are scientifically proportioned and graded in size so as to reduce the percentage of voids to the minimum giving the greatest density. It is theoretically possible to so grade the aggregates in regular progression from two to three inch stone down to distinct pieces the size of dust, so that the voids of each progressive volume are filled with the largest size particles that will fit them. Thus a minimum of cement will give a stronger concrete in compression than could be obtained with a larger percentage of cement, using same quality of sand and stone but not properly graded in size.

The ideal and practical, however, are entirely different matters. What the practical user of cement needs is practical information and not a mass of theories which obscure the vision and make it difficult for the "man in the field" to see the few simple laws and underlying principles which, if kept constantly in view, will lead to the best results.

Concrete should be considered as a whole, a definite material designed to meet the requirements of the particular work it has to perform; however, in order to intelligently consider concrete as a whole, we must analyze the function of each of the aggregates.

SELECTION OF THE LARGE AGGREGATES

In discussing the selection of aggregates, I will first deal with the larger size, for the reason that in proportioning the ingredients it is first necessary to measure the voids existing in any given quantity of the largest particles, so as to determine the quantity of mortar necessary to fill these voids. After selecting the best stone or gravel economically obtained in the particular locality in which the work is to be done, the next thought is the grading of this material so as to obtain maximum density, thus reducing the voids and consequently the amount of mortar required to furnish the bond.

Classification of Stone.

As the value of broken stone depends on several conditions, the following classification, read in the order in which they are stated, must be taken merely as a guide:

Trap, Quartz Gravel, Limestone (hard), Granite, Marble, Limestone (soft), Slag, Sandstone, Slate, Shale and Cinders. (N. B.—Poor grades of schist and all micaceous stone should not be used.) Among the conditions which must be taken into consideration are toughness and hardness as being better than stone which may be of a higher classification, but which is more easily fractured. The importance of toughness and hardness as related to strength, increases with the age of the concrete.

Purpose to Govern Selections.

The purpose for which the concrete is intended must always influence the selection. For a very strong concrete, a hard stone without any surface scale is necessary; a rich mortar will not entirely counterbalance a deficiency in the strength of the stone. For a medium strong concrete the hardest stone need not be insisted upon, but rather one to which the mortar will best adhere, such as some of the limestones. For fireproof construction some of the limestones and rocks containing feldspar should be avoided; good boiler furnace cinders have proved best for fire-resisting concrete.

Character of Fracture

For all classes of concrete, stone breaking in cubical form is far better than one breaking in flat layers such as shale or slate, it being almost impossible to ram or tamp such stone into as dense and compact a mass as that breaking in cubical fracture.

Presence of Screening or Quarry Tailings

The size of the stone aggregates depends on the purpose for which the concrete is to be used. For large masses of concrete, 2½ inch stone is usually considered the maximum size, but for 12 inch walls and the usual class of concrete construction, ¾ inch will be found sufficiently large. In considering the selection of broken stone, it must be borne in mind that screenings, quarry tailings, etc., in crushed stone, are not a detriment, as is commonly supposed, but in fact a decided advantage, for the reason that the voids are thus reduced, giving greater density and consequently greater strength; each particle is proportionately as strong as the largest piece of stone from which it came, unless stunned in crushing, as might occur in Granite and Sand Stones. When screenings are used as a portion of the larger aggregates in concrete, the (1-100 in. or less dust) should not be in excess of 10 per

cent. of the volume of screenings, which will pass a $\frac{1}{4}$ inch mesh, as the dust is apt to coat the stone so that the mortar does not come as readily in direct contact with the larger pieces of stone. If, through careful mixing, the mortar does happen to reach every portion of the surface of the larger aggregates, it is from necessity made less rich by the dust; therefore, dust and other particles which will pass through a $\frac{1}{4}$ or $\frac{1}{8}$ inch mesh should be screened out and used as part of the mortar.

Material which is foreign to the stone, such as vegetable mold, scale, or loam, which cling to the surface, will reduce the strength of the concrete. This again is largely a question of careful and thorough mixing. Numerous tests conducted during the last several years by competent engineers have shown that clay in small proportions, not over 15 per cent., when well mixed in the mortar, does not reduce the strength of the concrete; in fact, tests have shown that the strength has been increased. This applies particularly to the leaner mixtures. If carefully mixed, therefore, the clay will not cling to the stone, but will become part of the mortar.

Gravel.

Gravel is often superior to broken stone, being usually found graded from coarse to fine; the roundness of the pebbles lends aid to compactness. It is not likely to bridge and leave holes in the concrete. The percentage of voids is usually less than in broken stone; the quartz pebbles are harder, stronger and less liable to fracture. In this discussion quartz pebbles or other very hard pebbles are referred to; sand stone pebbles are not considered as good as the better grades of crushed stone. The usual argument against gravel is that the mortar is not supposed to adhere as well to the surface as to that of freshly broken stone. This is one of the theories which is practically due to the appearance of the surface to the eye or touch; the adhesion of mortar to lime stone of a smooth surface may be far greater than to sand stone or rougher materials. If roughness was the only requirement for adhesion it would seem impossible to cement together two pieces of glass.

From the standpoint of durability, gravel must be superior to stone for the reason that, by the laws of the survival of the fittest and by process of elimination, nature has supplied us with the most durable. Short time tests for compression strength usually show broken stone concrete to be superior, but long time tests of from six months to a year show gravel concrete on an average to be equal if not stronger.

There is much more to be said on the subject of the selection of the larger aggregates, but the writer believes that the ground has been covered sufficiently for practical purposes.

MORTAR FOR CONCRETE

Mortar for concrete is composed of Portland Cement and sand (preferably coarse, but graded in size), or other fine materials, such as crushed stone, all of which will pass a $\frac{1}{4}$ inch sieve. Considering the mortar, we have to keep in view the purpose to which the concrete, as a whole, is to be put, so as to judge the necessary strength of the mortar.

Selection of Screenings or Quarry Tailings for Mortar.

In the selection of screenings or quarry tailings, these materials should be from hard, tough stone and free from mica, loam, peaty matter, decayed particles and scale. If used as the entire aggregate for mortar without addition of any sand, 33 per cent. of dust has given good results, as is demonstrated in the manufacture of Architectural Cement Stone, which is now being made in considerable quantities by the use of sand moulds. Limestone screenings graded in size from $\frac{1}{4}$ inch to fine dust have in numerous instances given greater strength than has mortar made of the same quantity of the best sand. It will also be found that the resulting mortar is denser than a sand mortar, and thus better for waterproofing purposes.

The character of the particles, whether they be flat or cubical in the matter of quarry tailings, has little to do with the dense mortar which is obtained by their use. That the mortar is dense is a practical fact, and as this paper is not a theoretical treatise, I do not feel called upon to go deeply into the theory which will explain these results, excepting to briefly outline that the

density depends on the proper graduation in size of the particles and the percentage of very fine particles and dust present.

There can be no reasonable doubt that with the best material the densest concrete will be the strongest under compression. This idea can be readily grasped if you will eliminate tensile strength from your mind, as concrete is designed almost entirely for compression.

It so happens, however, that quarry tailings or screenings from the best crushed stone when made into briquettes for tensile strength tests, will show far greater tensile strength in long time periods than will the best quality of sand mixed in the same proportions. The writer has in his possession a broken briquette made of one part Vulcanite Portland Cement, 2½ parts quarry tailings which contained 33 per cent. of fine dust, which briquette in two years' time broke at 1000 lbs. per square inch.

Selection of Sand for Mortar.

We now come to the selection of Sand. The value of sand for concrete mortar depends largely on its coarseness, graduation in size of the grains, and cleanliness.

Character of Sand Grains.

The sharpness of the grains of sand has little to do with its value. It has commonly been supposed that sand should be sharp. This, however, is one of the theories which has been exploded. The writer has never seen any tangible reason for such theory. In fact, there are many arguments in favor of coarse, round grain sand. Compactness is what is desired, giving density to the mortar; round grains compact more readily than sharp grains, and the cement will cling to the surface of round grains as well as sharp grains, the character of the surface being identical. Sharp sand is only of value as indicating a silicious sand.

Good sand cannot be easily defined, or an inflexible specification written, as sands of various properties may make equally good concrete. All things being equal, a coarse sand containing a large percentage of coarse particles is far superior to a fine sand in which few coarse particles are present. The full strength of any cement cannot be developed with a sand, all the particles of which are

fine, or so fine as to all pass through a 30 mesh sieve and not graduated in size of particles.

Graduation in Size of Sand Grains.

Economy can be practiced in the matter of the selection of sand. It will nearly always pay the concrete constructor to haul sand even from a considerable distance, paying a higher price, provided he cannot get a sand in the immediate locality of the work, which sand is so graduated in size of grains as to give the greatest density.

Increase of Voids in Damp Sand.

When water is added to dry sand of peculiar characteristics it swells in volume. This is due to the grains being coated with water and by capilary attraction thus pried apart. Thus we have more voids in a cubic foot of some damp sands than we have in a cubic foot of the same sands when dry. Some sands are not well graded in size of particles and will necessarily take up more water than other sand.

Loam, Mica.

Sand containing loam is dangerous for two reasons; one is that loam may chemically react on the Portland Cement causing slowness of hardening, the other is that the loam coats the grains of sand preventing proper adhesion. Sand containing over 5% of mica should not be used.

Clay.

Clay in small percentage will do no harm to sand, providing the sand and cement are thoroughly mixed with a sufficient percentage of water to detach the clay from the sand grains and intimately mix same with the cement, the clay being colloidal in character and of finer particles than the cement, mechanically combines with the cement, producing greater density.

However, it is not safe to use sand containing clay in excess of 15% of the volume of the sand. It is often difficult to determine the difference between certain kinds of clay and loam. Experienced contractors can often judge by feeling; the loam causing a slimy feeling is darker in color, and not as readily washed from the sand particles.

For field work possibly the best test to determine the sand which will produce the greatest density is by means of the water void test properly applied and properly read. Laboratory tests which involve the

use of Portland Cement in determining the sand which will produce the densest mortar is a lengthy procedure.

FIELD METHOD FOR OBTAINING VOIDS IN SAND OF VARIOUS CHARACTERISTICS.

Water tests for Voids.

The void test by use of water should be done in a graduated glass tube. Supply two glass tubes $1\frac{1}{2}''$ to $2\frac{1}{2}''$ in diameter, containing 200 cubic centimeters or over, and marked by a graduated scale divided into cubic centimeters.

Dry the sample of sand to be tested by spreading a thin layer in a pan or over a piece of tin and heating same to a temperature of over 212° F. The reason for drying the sand is to arrive as nearly as possible at an accurate unit of measurement, so that the proportion of cement to sand, which will be described later, may be ascertained. When this sand is cool measure out in the graduated glass tube 100 c.c. of this dry sand; be careful to pour slowly into the tube, jarring the tube while pouring. Level off the top with a flat end stick so as to accurately read the measurement.

In the other glass tube, measure out 100 c.c. of water. Pour the dry sand slowly into the glass tube containing the water and note the height to which the water rises. Also note the number of c.c. of the sand. The sand will not always measure when wet exactly the number of c.c. as when dry, namely 100, as some sands, as previously stated, due to peculiar characteristics, swell in volume when moist or wet.

If 100 c.c. of solid matter had been placed in the glass tube the water would have risen to 200. Therefore, to ascertain the voids, deduct the number of c.c. to which the water has risen from 200. Sand as it comes from the bank or is measured by contractors is always damp or wet; it is assumed that it has swelled to its maximum volume.

If it is found that the sand has swelled in volume then the number of c.c. to which it has swelled over and above 100 must be considered.

As an illustration: 100 c.c. of Cheshire White Quart-

zite, medium, was placed in 100 c.c. of water. It was found that the White Quartzite then measured 114 c.c., showing that it had swelled in volume 14 c.c., thus under working conditions increasing the voids. Therefore, if 114 c.c. of solid matter had been added to 100 c.c. of water, the water would have risen to 214 c.c. It was found, however, that the water only rose 156 c.c., therefore, there is 58 c.c. of voids in the 114 c.c. of sand; divide 58 by 114 and you get 50 8-10% of voids.

For convenience the following table will give the calculations for the percentage of voids:

TABLE No. 1.

100 C. C. Dry Sand Added to 100 C. C. Water.

(C.C. Stands for Cubic Centimeter.)

Water rose to	Sand Swelled in Volume to Following c.c.														
	100 Constant	101	102	103	104	105	106	107	108	109	110	111	112	113	114
	Percentage of Working Voids.														
150	50	50^5	50^9	51^4	51^9	52^4	52^8	53^3	53^7	54^1	54^5	55	55^3	55^7	56^1
151	49	49^5	50	50^5	51	51^4	51^9	52^3	52^8	53^2	53^6	54	54^4	54^8	55^2
152	48	48^5	49	49^5	50	50^5	50^9	51^4	51^9	52^3	52^7	53^1	53^6	53^9	54^3
153	47	47^5	48	48^5	49	49^5	50	50^5	50^9	51^4	51^8	52^3	52^6	53	53^5
154	46	46^5	47^1	47^6	48	48^6	49^1	49^5	50	50^5	50^9	51^4	51^7	52^2	52^6
155	45	45^5	46^1	46^6	47^1	47^6	48^1	48^6	49^1	49^5	50	50^4	50^8	51^3	51^7
156	44	44^5	45^1	45^6	46^1	46^7	47^2	47^7	48^1	48^6	49^1	49^5	50	50^4	50^8
157	43	43^5	44^1	44^6	45^1	45^7	46^2	46^7	47^2	47^7	48^2	48^6	49^1	49^5	50
158	42	42^5	43^1	43^7	44^2	44^7	45^3	45^8	46^3	46^8	47^3	47^7	48^2	48^6	49^1
159	41	41^5	42^1	42^7	43^3	43^8	44^3	44^9	45^4	45^9	46^4	46^8	47^3	47^7	48^2
160	40	40^6	41^2	41^7	42^3	42^8	43^4	43^9	44^4	44^9	45^5	45^9	46^4	46^9	47^3
161	39	39^6	40^2	40^8	41^3	41^9	42^4	43	43^5	44	44^5	45	45^5	46	46^4
162	38	38^6	39^2	39^8	40^4	40^9	41^5	42^1	42^5	43^1	43^6	44^1	44^6	45^1	45^6
163	37	37^6	38^2	38^8	39^4	40	40^6	41^1	41^6	42^2	42^7	43^2	43^7	44^2	44^7
164	36	36^6	37^3	37^9	38^5	39	39^6	40^2	40^7	41^3	41^8	42^3	42^8	43^3	43^8
165	35	35^6	36^3	36^9	37^5	38	38^7	39^2	39^8	40^4	40^9	41^4	41^9	42^4	42^9
166	34	34^6	35^3	35^9	36^5	37^1	37^7	38^3	38^9	39^4	40	40^5	41	41^5	42^1
167	33	33^6	34^3	34^9	35^6	36^1	36^8	37^4	38	38^5	39^1	39^6	40^1	40^7	41^2
168	32	32^7	33^3	34	34^6	35^2	35^8	36^4	37	37^6	38^2	38^6	39^2	39^8	40^3
169	31	31^7	32^4	33	33^7	34^2	34^9	35^5	36^1	36^7	37^3	37^8	38^3	38^9	39^4
170	30	30^7	31^4	32	32^7	33^2	33^9	34^6	35^2	35^8	36^4	36^9	37	38	38^6

In making field tests by the above described method of different samples of sand, use that which shows the least percentage of voids.

Clay or Loam.

Wash 100 c.c. of the sand in 100 c.c. of water by shaking together in a bottle, decant water into a graduated glass tube; again wash sample as before and decant water into the glass tube, stand until settled and read amount of clay or loam.

That the reader may have confidence in the methods above described in ascertaining the characteristics of sand which will produce maximum density, I will describe some of the experiments which I have made.

The use of a graduated glass tube of 1½″ to 2½″ in diameter containing 200 to 250 c.c. might appear to some engineers as being unreliable on account of the small quantities tested and the probable variation of volume. Also the theory of capilary attraction prying apart the grains of sand of certain characteristics might seem to be unsound, but numerous tests seem to bear out this theory. At any rate such peculiar characteristics have been noted by a number of engineers, but the writer has not yet run across any other theory which cannot be explained away. Some say that the head of the water used has different effects, that if a larger amount of water was used instead of 100 c.c., the results would be different. The writer, however, has not found this to be a fact and furthermore it would then be difficult to account for the sand which did not swell at all in volume.

I found, taking the average of one known sand, mixing it thoroughly, drying off the moisture and then measuring out 120 c.c., pouring it slowly into the glass tube and jarring the tube slightly while pouring, making a dozen or more samples and weighing each sample, that the difference in variation was about 2-64ths of an oz.; sufficient accuracy for practical purposes.

I also found by pouring this same sample of dry sand in a glass tube containing 100 c.c. of water, jarring the tube slightly while pouring, that the variation in the volume of sand as nearly as could be read was about ½ c.c.; sufficient accuracy for practical work. Further-

more the water rose to exactly the same height in each instance where the same sand was used.

The voids were calculated as previously described and then checked by means of the specific gravity test.

I have provided the following statement showing these results together with the sieve analysis of the sands tested.

TABLE No. 2.

Following added to 100 c.c. Water: added slowly and jarred.		Weight Sand, Dry.	Sand after settling in 100 c.c. water.	Water rose to	Actual voids in Dry Sand	Working voids in Wet Sand.	Sieves % collected on					
							4	10	20	30	50	Thru. 50
Rockaway Sand, fine, Cow Bay Sand, fine —a few very coarse particles.	mixed 25 c.c. ea. total 50 c.c.	$2\frac{60}{64}$	50 c.c.	132 c.c.	36%	36%	—	.03	$.08^{5}$	$.10^{3}$	$.37^{5}$	$.40^{7}$
Cow Bay Sand	50 c.c.	$2\frac{60}{64}$	51 c.c.	131 c.c.	38	39^{2}	—	$.08^{9}$	$.19^{1}$	$.19^{9}$	$.31^{9}$	$.20^{2}$
Rockaway Sand, fine	50 c.c.	$2\frac{60}{64}$	51 c.c.	131 c.c.	38	39^{2}	—	$.00^{3}$	$.00^{4}$	.01	$.31^{4}$	$.66^{9}$
Cheshire White Quartzite, medium	50 c.c.	$2\frac{34}{64}$	57 c.c.	128 c.c.	44	50^{8}	—	—	.39	.37	$.23^{5}$	$.00^{5}$
Cheshire White Quartzite, 65% coarse, 35% fine mixed	50 c.c.	$3\frac{12}{64}$	52 c.c.	134 c.c.	32	34^{6}	—	.53	$.11^{5}$	$.00^{2}$	$.04^{8}$	$.30^{5}$
Cow Bay Sand, fine particles sieved out	50 c.c.	$5\frac{47}{64}$	50 c.c.	131 c.c.	38	38	—	$.18^{5}$	$.40^{1}$	$.41^{4}$	—	—
Abbott Gully Sand	100 c.c.	$6\frac{3}{64}$	100 c.c.	165 c.c.	35	35	—	$.05^{9}$	$.12^{7}$	$.20^{2}$	$.36^{9}$	$.24^{3}$
Schenectady Brown Sand	100 c.c.	$5\frac{48}{64}$	105 c.c.	164 c.c.	36	39	—	—	$.00^{8}$	$.12^{2}$	$.67^{1}$	$.19^{9}$

To check these results the following calculations were made:

120 c.c. of Cow Bay sand with a preponderance of fine particles, when dry, weighed 7 12-64 oz. This is equivalent to 106 lbs. per cubic foot. If the specific gravity is 2.65 and 120 c.c. of Cow Bay sand weighed 7 12-64 oz., then the calculated percentage of voids is 36. Allowing for the sand having swelled slightly in volume, thus being compelled to calculate the working voids and furthermore, that the specific gravity is assumed, it will be seen that the results obtained by the water test were near enough correct for practical purposes.

Rockaway Sand.

I found that 120 c.c. of Rockaway Sand, which is a fine sea sand of the sieve analysis as shown in table No. 2, weighed 6 54-64 oz., which is equivalent to 102 lbs. per cu. ft. If the specific gravity of Rockaway Sand is 2.65 the calculated voids are 38%, which, allowing for the swelling of the volume of sand, proves the water

test as shown in the table to be near enough accurate for practical purposes.

I mixed up a sand composed of Cheshire White Quartzite, 65% coarse and 35% fine, of sieve analysis as shown in table above referred to; 50 c.c. were found to weigh 3 12-64 oz. As the specific gravity is 2.65, the calculated voids are 32%, which, allowing for swelling of volume, shows the water test to be correct.

Tensile Strength. Rockaway Sand and Various Proportions of Vulcanite Cement.

In order to futher ascertain as to the reliability of the water test for voids in sand as properly determined by the methods above described, I have carried on a series of tests on Rockaway sand. Used this character of sand for the reason that its sieve analysis apparently showed it to be a very poor grade of sand for mortar or concrete.

It will be noted that the water test on Rockaway sand showed 39^2% of working voids. By reference to table No. 4, this would give us a proportion of 1 part cement, 2½ parts sand. The following statement shows the results of tests and that these proportions are correct.

TESTS OF ROCKAWAY SAND.

PROPORTION	100 c.c. Sand gave a Volume of Mortar of	Average 5 Briquettes Tensile Strength 7 days	28 days	Collected on Sieve.	%
1:1½	125 c.c.	407	524	10	.003
1:1¾	120 c.c.	335	445	20	.004
1:2	120 c.c.	275	396	30	.01
1:2¼	115 c.c.	277	367	50	$.31^4$
1:2½	110 c.c.	255	334	Through	$.66^9$
1:2¾	110 c.c.	211	282		
1:3	110 c.c.	181	255		

5 5/16 oz. Cement figured as = to 100 c.c. which is in same proportion as 94 lbs.=one cu. ft.

You will note that 100 cubic centimeters of sand were used in each instance, and that when the cement in the varying proportions were added, the richest pro-

poroporion, 1 to $1\frac{1}{2}$ caused the volume to expand to 125 c.c., and that in the leanest proportion, 1 to 3, the volume expanded to 110 c.c.

This remained constant up to and including 1 to $2\frac{1}{2}$. The 1 to $2\frac{1}{4}$ went to 115, showing this to be too rich; the 1 to $2\frac{1}{2}$ being about right.

Tensile strain tests show that this mortar is amply strong, and that a 1 to 3 mix would be entirely too weak.

The difference between the water test above described and the water test which is in the minds of most engineers, is that previously little account was taken of the swelling of the volume of sand and there was no unit standardization of a volume of dry sand. If wet or damp sand is added to water, we cannot arrive at accurate results.

The best sand is that which will require the least amount of cement to produce maximum density, therefore, (taking into consideration the swelling) is that which contains the least percentage of voids. It is assumed that maximum density, the characteristics of the different sands being the same as far as the strength of the sand grains are concerned, is maximum strength.

Water

Water must be clear, odorless and tasteless. If there is taste or odor, the water must be analyzed, the chemist to advise if there is sufficient percentage of any elements present to be injurious to Portland Cement.

Selection of Portland Cement.

Now comes the most important ingredient in concrete, Portland Cement, as it is this material which forms the bond. The other aggregates being usually stronger, upon the uniform strength of the cement depends the strength of the concrete. The selection of stone, screenings, slag, cinders, sand or other ingredients can be determined often by sight or touch, or at least by simple tests. Portland Cement tests require experts of some years' experience; the results of known laboratory tests are merely a guide from which deductions may be made only by the best scientific understanding available. Owing to the variable conditions surrounding such tests, the results cannot be absolute.

Each manufacturer exploits his particular brand as the best cement, some claiming extraordinary fine grind-

ing the criterion, others larger bulk per barrel, others low lime content, others high lime content and hard burned clinkers, etc., etc., and all of them claim the strongest by test, which claims they support by various published test sheets.

Specification for Portland Cement.

In order to select the best grade of cement for very important work, the engineer or constructor should specify the requirements of the Standard Specifications as adopted by the American Society of Civil Engineers and American Society for Testing Materials, as published by the Association of American Portland Cement Manufacturers, copies furnished by any manufacturer of Portland Cement on application. He should then select for purchase the brand that is produced by manufacturers of experience and reputation, as ascertained from engineers, not one but a number, their experience extending over at least five years with several of the well known brands. Having selected one or more brands of the best reputation, he can hold as check against errors or mistakes in manufacture the test described by the specifications above referred to. The brand purchased will necessarily not be the cheapest, but results will undoubtedly prove such brands to be more economical, as less cement may with safety be used; that of the universally best reputation is more liable to be uniform. This method of selecting Portland Cement always gives the user the best material obtainable at the fairest price, making it to the advantage of the manufacturers to produce for the engineer's interest, also offering an incentive to the manufacturer to produce the best product at all times, making improvement as science advances.

PROPORTION OF AGGREGATES.

The previous part of this pamphlet has been devoted to a brief description of what is now almost universally considered as the best ingredients for the manufacture of concrete. The following are some field methods for properly proportioning these ingredients so as to produce maximum density and therefore water-tight concrete.

Please keep in mind that concrete is composed of mortar which binds together crushed stone, pebbles, crushed slag or cinders. If the mortar is not dense, the concrete is not only weak but is not water-tight.

Mortar.

We will first consider the methods of proportioning Portland Cement and sand or stone screenings, all passing through a $\frac{1}{4}''$ mesh, which compose the mortar, and then later on consider the methods for proportioning crushed stone or pebbles or the other large aggregates, so that this dense mortar entirely fills the voids, allowing for some excess of mortar, probably about 10%, which will care for any unevenness in mixing or placing.

For field purposes the same methods may be used in proportioning as were described in selecting the sand. A standard for measurement is a necessity. The unit for measurement should be Portland Cement, 94 lbs., one bag, equivalent to one cu. ft., the other aggregates or ingredients figured on this unit. The expression of the proportions as universally adopted is to first state the amount of cement, second the amount of sand or stone screenings, and third the amount of large aggregates; each figure representing the proportions divided by a colon; thus 1 part of cement, 2 parts of sand, and 4 parts of crushed stone, would be shown as 1:2:4.

By reference to various authorities, a barrel (4 bags) of Portland Cement as packed by the manufacturer measures approximately 3.8 cu. ft. The figures in table No. 4 are arrived at on this basis. It can, therefore, be readily seen that if this table is used, or the same calculations are employed, 94 lbs. of Portland Cement may be, for purposes of convenience, considered as a cu. ft. and maximum density result.

I have carried on a large number of experiments based largely on laboratory methods, which experiments tend to show that 3.8 cu. ft. to the barrel of Portland Cement weighing 376 lbs. net, is approximately correct.

If 3.8 cu. ft. weigh 376 lbs., then 100 c.c. will weigh 5 19-32 oz., so if it is assumed that 1 bag of Portland Cement, 94 lbs., is a cu. ft., then 100 c.c. would = 5 5-16 oz.

10% Increase in Volume of Mortar.

Using the calculated voids as per the water test above referred to, and the proportion of cement accordingly, using as a unit of measurement 94 lbs. as assumed to be equivalent to 1 cu. ft., or 100 c.c. as equivalent to 5 5-16 oz., I found that the volume of mortar was entirely dense, economical and in every instance greater than the volume of sand used to the extent of from 10 to 15%; therefore, irregularities in mixing and placing are automatically cared for.

I believe it necessary to go to this lengthy explanation in order that the methods and tables may be thoroughly understood, and being understood the field engineer may arrive at practical results by the use of the instructions which follow:

Avoid using sand composed of a preponderance of one size grains.

METHOD USED TO ARRIVE AT CORRECT PROPORTIONS.

Obtain the voids in sand by means of the graduated glass tube water test as described on Page 10. Use following Table No. 3.

TABLE No. 3.

100 C. C. Dry Sand Added to 100 C. C. Water.

(C.C. Stands for Cubic Centimeter.)

Water rose to	Sand Swelled in Volume to Following c.c.														
	100 Constant	101	102	103	104	105	106	107	108	109	110	111	112	113	114
	PERCENTAGE OF WORKING VOIDS.														
150	50	50^5	50^9	51^4	51^9	52^4	52^8	53^3	53^7	54^1	54^5	55	55^3	55^7	56^1
151	49	49^5	50	50^5	51	51^4	51^9	52^3	52^8	53^2	53^6	54	54^4	54^8	55^2
152	48	48^5	49	49^5	50	50^5	50^9	51^4	51^9	52^3	52^7	53^1	53^6	53^9	54^3
153	47	47^5	48	48^5	49	49^5	50	50^5	50^9	51^4	51^8	52^3	52^6	53	53^5
154	46	46^5	47^1	47^6	48	48^6	49^1	49^5	50	50^5	50^9	51^4	51^7	52^2	52^6
155	45	45^5	46^1	46^6	47^1	47^6	48^1	48^6	49^1	49^5	50	50^4	50^8	51^3	51^7
156	44	44^5	45^1	45^6	46^1	46^7	47^2	47^7	48^1	48^6	49^1	49^5	50	50^4	50^8
157	43	43^5	44^1	44^6	45^1	45^7	46^2	46^7	47^2	47^7	48^2	48^6	49^1	49^5	50
158	42	42^5	43^1	43^7	44^2	44^7	45^3	45^8	46^3	46^8	47^3	47^7	48^2	48^6	49^1
159	41	41^5	42^1	42^7	43^3	43^8	44^3	44^9	45^4	45^9	46^4	46^8	47^3	47^7	48^2
160	40	40^6	41^2	41^7	42^3	42^8	43^4	43^9	44^4	44^9	45^5	45^9	46^4	46^9	47^3
161	39	39^6	40^2	40^8	41^3	41^9	42^4	43	43^5	44	44^5	45	45^5	46	46^4
162	38	38^6	39^2	39^8	40^4	40^9	41^5	42^1	42^5	43^1	43^6	44^1	44^6	45^1	45^6
163	37	37^6	38^2	38^8	39^4	40	40^6	41^1	41^6	42^2	42^7	43^2	43^7	44^2	44^7
164	36	36^6	37^3	37^9	38^5	39	39^6	40^2	40^7	41^3	41^8	42^3	42^8	43^3	43^8
165	35	35^6	36^3	36^9	37^5	38	38^7	39^2	39^8	40^4	40^9	41^4	41^9	42^4	42^9
166	34	34^6	35^3	35^9	36^5	37^1	37^7	38^3	38^9	39^4	40	40^5	41	41^5	42^1
167	33	33^6	34^3	34^9	35^6	36^1	36^8	37^4	38	38^5	39^1	39^6.	40^1	40^7	41^2
168	32	32^7	33^3	34	34^6	35^2	35^8	36^4	37	37^6	38^2	38^6	39^2	39^8	40^3
169	31	31^7	32^4	33	33^7	34^2	34^9	35^5	36^1	36^7	37^3	37^8	38^3	38^9	39^4
170	30	30^7	31^4	32	32^7	33^2	33^9	34^6	35^2	35^8	36^4	36^9	37	38	38^6

Apply following table No. 4, using the proportions as shown in last column opposite the % of voids as ascertained above.

Proportions of cement and sand resulting in maximum density for water-tight mortar.

(Voids to be determined by method described above). Proportions figured on 4 bags=3.8 cu.ft. Proportions stated, 1 bag=1 cu.ft.

TABLE No. 4.

% Voids in Sand.	PROPORTIONS. Figuring actual volume of 1 bbl. cement as packed by Mfgrs. to =3.8 cu. ft. and assuming 1 bag=1 cu. ft.	Proportions to use figuring 1 Bag cement=to 1 cu. ft. Figures are nearest the ¼.	% Voids in Sand.	PROPORTIONS. Figuring actual volume of 1 bbl. cement as packed by Mfgrs. to=3.8 cu. ft. and assuming 1 bag=1 cu. ft.	Proportions to use figuring 1 Bag cement=to 1 cu. ft. Figures are nearest the ¼.
	cu. ft.			cu. ft.	
25	1:3.76	1:3¾	38	1:2.47	1:2½
26	1:3.61	1:3½	39	1:2.41	1:2½
27	1:3.48	1:3½	40	1:2.35	1:2¼
28	1:3.35	1:3¼	41	1:2.29	1:2¼
29	1:3.24	1:3¼	42	1:2.23	1:2¼
30	1:3.13	1:3¼	43	1:2.18	1:2¼
31	1:3.03	1:3	44	1:2.13	1:2¼
32	1:2.93	1:3	45	1:2.09	1:2
33	1:2.85	1:2¾	46	1:2.04	1:2
34	1:2.76	1:2¾	47	1:2	1:2
35	1:2.66	1:2¾	48	1:1.96	1:2
36	1:2.61	1:2½	49	1:1.91	1:2
37	1:2.54	1:2½	50	1:1.88	1:1¾

Proportions of Cement to Screenings or Quarry Tailings.

In the matter of screenings or quarry tailings all passing a ¼″ square mesh sieve, thereby taking the place of sand above referred to, arrive at the voids in the screenings or quarry tailings in exactly the same manner as you arrived at the voids in the sand as described on Page 10, using Table 3, with the exception that a larger diameter graduated glass tube should be used, say about 2½ inches or over in diameter.

Proportions of Crushed Stone or Larger Aggregates.

Next consider the proportions of crushed stone, pebbles or larger aggregates by means of ascertaining the voids. Please keep in mind that the voids are to be filled with mortar as previously described. The Table which gave the proportions of cement to sand composing the mortar has automatically cared for an increase in volume of approximately 10%.

To ascertain the percentage of voids in the larger aggregates, the following table will be a simple means of furnishing this information.

Make a box of such dimensions as will contain 3 cu. ft., box to be 1′x1½′x2. Dry the stone or gravel, heating to over 212° F. Throw the stone into the box loose, level off the top with a straight edge, and having first weighed the box, weigh the box when full. Deduct the weight of the empty box from the gross weight and divide the net weight by 3, which will give the actual weight of 1 cu. ft. Apply following table.

PERCENTAGE OF VOIDS.

Weight per Cubic Foot-lbs	Gravel (Pebbles) without Sand	Sandstone	Limestone medium soft	Limestone medium hard; Sandstone hard	Granite Blue stone Limestone hard	Granite hard Trap medium	Trap hard
75	54	50	52	54	—	—	—
80	51	47	49	51	52	—	—
85	48	43	45	48	50	51	—
90	45	40	42	45	47	48	50
95	42	37	39	41	44	46	47
100	39	33	36	38	41	43	45
105	36	30	33	35	38	40	42
110	33	26	29	32	35	37	39
115	30	—	26	29	32	34	36
120	27	—	—	26	29	31	34
125	—	—	—	—	26	28	31
130	—	—	—	—	—	26	28
135	—	—	—	—	—	—	25

Before ascertaining the voids in stone containing screenings or gravel containing sand, dry by heating, screen out all particles which will pass through a ¼″ mesh sieve; such particles should be figured as a portion of the mortar. Having obtained the percentage of voids in the larger aggregates, the proportion of mortar necessary to fill these voids is thus known.

You are now in possession of the proportions of cement to sand or stone screenings in forming the mortar

and the number of voids in the larger aggregates which will be filled with this mortar. The following Table (Table No. 5) will be a ready means for obtaining the proportions for concrete.

For instance: If the sand you have selected for use requires a proportion of 1 part cement, 2½ parts sand, (1:2½), to produce maximum density of the mortar and your available stone is hard crushed granite 1″ size, and you find a cu. ft. of this hard crushed granite weighs 100 lbs., there will be 43% of voids. Refer to the following table and you will find that the proportions producing maximum density in the concrete to be 1 part cement, 2½ parts sand, and 5¾ parts crushed granite.

The unit for measurement being 94 lbs. (1 bag) of Portland Cement as being equivalent to 1 cubic foot. Proportions of mortar expressed 1 part cement, parts sand (1:1 to 1:4½).

TABLE No. 5.

Voids in Stone	Proportions of Stone expressed in cubic feet											
	PROPORTIONS OF MORTAR											
%	1:1	1:1¾	1:2	1:2¼	1:2½	1:2¾	1:3	1:3¼	1;3½	1:3¾	1:4	1:4½
25	4	7	8	9	10	11	12	13	14	15	16	18
26	3¾	6¾	7¾	8½	9½	10½	11½	12½	13½	14½	15½	17¼
27	3½	6½	7½	8¼	9¼	10	11	12	13	14	14¾	16¾
28	3½	6¼	7¼	8	9	9¾	10¾	11½	12½	13½	14¼	16
29	3½	6	7	7¾	8½	9½	10½	11¼	12	13	13¾	15½
30	3¼	5¾	6¾	7½	8¼	9¼	10	10¾	11¾	12½	13¼	15
31	3¼	5¾	6½	7¼	8	9	9¾	10½	11¼	12	13	14½
32	3	5½	6¼	7	7¾	8½	9¼	10	11	11¾	12½	14
33	3	5¼	6	6¾	7½	8¼	9	9¾	10¾	11½	12	13¾
34	3	5¼	6	6½	7¼	8	8¾	9½	10¼	11	11¾	13¼
35	2¾	5	5¾	6½	7¼	7¾	8½	9¼	10	10¾	11½	12¾
36	2¾	5	5½	6¼	7	7¾	8	9	9¾	10½	11	12½
37	2¾	4¾	5¼	6	6¾	7½	8	8¾	9½	10¼	10¾	12¼
38	2¾	4¾	5¼	6	6½	7¼	8¼	8½	9¼	10	10½	11¾
39	2½	4½	5	5¾	6¼	7	7¾	8¼	9	9¾	10¼	11½
40	2½	4½	5	5¾	6¼	7	7½	8	8¾	9½	10	11¼
41	2½	4¼	4¾	5½	6	6¾	7¼	8	8½	9¼	9¾	11
42	2¼	4¼	4¾	5½	6	6½	7¼	7¾	8¼	9	9¼	10¾
43	2¼	4	4¾	5¼	5¾	6½	7	7½	8¼	8¾	9¼	10½
44	2¼	4	4½	5¼	5¾	6¼	6¾	7½	8	8½	9	10¼
45	2¼	4	4½	5	5½	6	6¾	7¼	7¾	8¼	8¾	10
46	2¼	3¾	4¼	5	5½	6	6½	7	7¾	8¼	8¾	9¾
47	2¼	3¾	4¼	4¾	5¼	5¾	6¼	7	7½	8	8½	9½
48	2	3¾	4	4¾	5¼	5¾	6¼	6¾	7¼	7¾	8¼	9¼
49	2	3½	4	4½	5	5½	6¼	6¾	7	7¾	8¼	9¼
50	2	3½	4	4½	5	5½	6	6½	7	7½	8	9
51	2	3½	3¾	4½	5	5½	6	6½	6¾	7¼	7¾	8¾
52	2	3¼	3¾	4¼	4¾	5¼	5¾	6¼	6¾	7¼	7¾	8¾
53	2	3¼	3¾	4¼	4¾	5¼	5¾	6¼	6¾	7	7½	8½
54	2	3¼	3¾	4¼	4¾	5	5½	6	6½	7	7¼	8½

It will often pay the engineer or contractor to mix together two different sizes of crushed stone or two different sizes of pebbles, say one size of 2″ and one size of ¾″, etc. The proportion of 2″ stone and the proportion of ¾″ stone, or such other sizes as may be convenient, can be ascertained by a simple method as follows:

Make a receptacle which will hold a little over 4 cu. ft., say a piece of 15″ sewer pipe. Measure 3 cu. ft. of the larger size stone and 1 cu. ft. of the smaller size stone, mix well together and place in the receptacle, marking the receptacle on the side the height to which the stone rises. Empty the receptacle and again measure 2 cu. ft. of larger stone and 2 cu. ft. of the smaller stone, mix as before, placing in the receptacle and note on the side the height to which the stone rises. Vary the proportions, measuring in the same manner as before, always adhering to a total of 4 cu. ft. The mixture which produces the least volume in the receptacle will make the densest concrete. The voids in this mixture can be ascertained by the use of Table on page 22.

Illustration:—The best stone obtainable being a hard limestone, which has been selected crushed in sizes of, say, 1½ inch, and ½ inch. These sizes mixed together are found to weigh 120 lbs. per cubic foot (see table page 22), voids are therefore 29 per cent. The available sand in locality requires (by test), 1 part cement, 2½ parts sand, to meet the requirements of the character of work to be done, but by purchasing a sufficient quantity of coarse sand at a point distant to mix with the local sand, a far greater density results; which mixture allows a proportion of 1 part cement to 3 parts sand; therefore, the relative proportion giving maximum density as per above table will be 1 part (95 lbs.) cement, 3 cubic feet of sand, 10½ cubic feet of stone. As there may be conditions due to character or size of particles of stone and sand which would effect the volume, hence density of the whole, it might be well when a reasonable doubt exists to apply same method to the stone with sand and cement added in the determined proportion as was applied in determining a mixture of two or more sands and the proportion of cement to sand. To test the total

mixture of all the ingredients use a piece of 8 or 12 inch sewer pipe, mix wet and tamp, making several test samples. Note proportion of stone used in each sample, use that containing the largest amount of stone which is just short of increasing the volume of concrete. The proportion of cement to sand remains the same, the proportion having been accurately determined by test in the glass tube.

It is altogether a reasonable proposition to state that these proportions made of selected ingredients above described produce a concrete which is actually stronger and more dense than if the concrete had been made of unselected local aggregates. And also allows an immense saving in cement.

The method above described of proportioning the aggregates as opposed to the usual practice of specifying arbitrary proportions regardless of the character of the available ingredients or of the work to be done, has the advantage of offering an incentive to good workmanship. While the aggregates may in some instances prove more expensive, the resulting concrete actually costs less per yard. With expensive aggregates the contractor and foreman will take less chances of waste, and therefore exert more care in mixing and in placing. Arbitrary specifications written by the architect or engineer, which simply state good sand and stone shall be used together with Portland Cement, meeting certain tests, mixed in proportions of 1-2-4 or 1-3-6, as the case may be, may mean a very rich concrete, or again may result in a very lean mixture. Supposing the only available aggregates which can be used in the locality in which the work is to be done, proves to be a stone breaking in flat layers which does not compact so as to give less than 52 per cent. in voids, a 1-2-4 mixture would not give the maximum density, it would be too lean. Then again the aggregates may prove to be a very good grade of stone, which are crushed ¾ inch sizes, well graded down to particles which are just short of passing a ¼ inch mesh, and the voids are found to be 30 per cent., your mixture is then entirely too rich. These two propositions are sufficient to illustrate the fallacy of arbitrary proportions.

It is a reasonable proposition and one within reach, that the ultimate strength for concrete can be figured within a small margin, provided the character of aggregates are known and the proportion of such aggregates definitely stated, which will give maximum density.

The thought of maximum density should be kept constantly in mind and the idea of a fixed arbitrary proportion eliminated, for the character of the available aggregates will entirely govern the proportions which will give the strongest concrete.

LABORATORY METHOD OF OBTAINING CORRECT PROPORTION OF PORTLAND CEMENT TO SAND OR STONE SCREENINGS FOR MORTAR.

Provide several graduated glass tubes containing 200 to 250 cubic centimeters, with a scale on the side divided into cubic centimeters. Also provide a scale which will balance accurately to a sixty-fourth of an ounce.

In proportioning mortar for actual work, it is convenient to assume 94 lbs. net (1 bag of Portland Cement) as being equivalent to 1 cu. ft. Therefore, in making test samples to determine the percentage of cement to any given quantity of sand which will produce a maximum dense mortar, it is well to take 2 42-64 oz. of cement as being equivalent to 50 c.c.

This is figured as follows: Assuming 4 cubic feet weighs 376 lbs. (the actual is, 3 8-10 cubic feet weighs 376 lbs.) then 100 c.c. weighs .331948 lbs., or 2324 grains, or 5 5-16 oz. or 50 c.c. 2 42-64 oz., so that we can preserve the standard of measurement of 1 bag, 94 lbs., being equal to 1 cu. ft., which for practical purposes is more convenient for measurement.

Weigh several samples of cement of 2 42-64 oz. each (50 c.c., Measure out several samples of sand from 87½ to 150 c.c. each, so that you will have a proportion of cement to sand as follows: 1:1¾, 1:2, 1:2¼, 1:2½, 1:2¾, and 1:3.

The sand should be dried before measuring. To measure the sand accurately, pour the dry sand slowly into the tube, jarring the tube while pouring. Mix 2 42-64 oz. of Portland Cement with each sample of sand thus measured. Add sufficient water to make a mortar which when tamped in the glass tube will not cause any water to rise to the surface. The consistency of the mortar to be about the same as that used in making sand briquettes for tensile strength by the standard methods of testing.

Place a little of this mortar at a time in the graduated glass tube —not over 4 c.c. at one time. Press down hard with a flat-end stick

leaving some space between the flat-end stick and the side of the tube for the expulsion of air. Pack this mortar as tightly as possible in this graduated glass tube. Note the space occupied by each sample. It will be found that the total volume of any one sample will exceed the volume of the sand alone.

The sample containing maximum density will be that which contains (in progression) the largest amount of sand, but has not appreciably increased the volume of mortar. For instance: refer to Page 17, under the heading of "Tests of Rockaway Sand." You will find by this method that the sample containing proportions of 1:3 gave a volume of 110 c.c., 1:2¾ gave 110 c.c., 1:2½ gave 110, and the 1:2¼ gave 115 c.c. Therefore, the 1:2½ is the sample which should theoretically produce maximum density of the mortar. The 1:2¼ would be too rich, and the 1:3 too lean.

The cement having been measured by weight in each instance—the unit of measurement for the cement being 94 lbs., 1 bag of cement assumed to be equivalent to 1 cu. ft., calculated on the actual volume of a barrel of cement as being 3.8 cu. ft.—the quantity of sand being measured and noted for each sample, you are thus in possession of the proportions required for a mortar for use in actual work. This refers entirely to concrete in which maximum density is required; such concrete will be almost impervious to water.

This test should be carried further and samples made of exactly the same proportions but larger in volume, so that tensile strain briquettes may be made to be broken in 7 and 28 day periods. As a matter of interest a sieve analysis should be made of the sand.

Having obtained the volume of mortar produced by each sample and the tensile strength of each sample, you can then determine as to whether a mortar of less density may with safety be used for work which does not require a water-tight concrete.

For instance, in the matter of the test of the Rockaway Sand, if the maximum density was not required a proportion of 1:2¾ might have been used, for it is found that such proportion gave a strength in 7 days of 211 lbs., and in 28 days of 282 lbs., amply strong for ordinary concrete work.

In the matter of screenings or quarry tailings for mortar, all of which will pass through a ¼″ sieve and not containing over 10% of dust—that which would pass through a 100 sieve—you may obtain the proportion of cement to screenings or quarry tailings which will produce maximum density, in the same manner, with the possible ex-

ception that a larger diameter graduated glass tube should be used on account of the shape of the particles of the quarry tailings.

By the method above described the relation of weight to volume is standard, these figures being based on 94 lbs. of cement as being equal to 1 cu. ft. Therefore, it makes no difference whatever if this be actual or not. Thus the variations in different brands of cement are automatically cared for, providing the same brand is used to determine the proportions for mortar as will be used in the actual work. These tests should be carried on with various sands, as there may be two or more sands obtainable in the same locality, one of which might require much less cement than the other and yet obtain maximum density in the mortar, effecting considerable economy on a large job.

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The Economy of Portland Cement is in Rapid Hardening

1895—14,000 bbls. per annum

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Reasons for "VULCANITE'S" Splendid Reputation

A brand of Portland Cement showing constantly and with uniformity the characteristics of correct composition, soundness, a large percentage of impalpable powder (flour), great strength in long-time periods, coupled with slow setting and rapid hardening, is one which contains a larger percentage of lime and alumina.

The "VULCANITE" Brand manufactured by the Vulcanite Portland Cement Co. contains a greater per cent. of lime and alumina than other cements. "VULCANITE" sets in approximately 7 hrs. 30 min. final—a slow setting cement. It is at the same time rapid hardening, becoming as hard and strong in from 3 to 4 days as other cements are in 7 days, and is even stronger in 7 days than some cements are in 28 days. It continues to gather strength with age.

The cement rock and limestone quarries owned and operated by the Vulcanite Portland Cement Co. are the most uniform in the famous Lehigh Valley region.

The fact that "VULCANITE" is burned at a very high temperature produces a cement of exceptional hardness, making it particularly adapted to sidewalks, pavements and floors, for which it has been preferred for a great number of years.

The fine grinding of intimately mixed, properly proportioned raw materials is of far greater importance than the extra fine grinding of the finished product. The character of grinding is of considerable importance. A mill should be used which will produce the largest percentage of impalpable powder (flour). Do not be misled into thinking one cement is finer than another, containing more flour, because a larger percentage passes through a 200 sieve. There is no sieve manufactured containing over 40,000 meshes to the square inch. This is known as a No. 200 sieve. Portland Cement may be ground so that all the particles will pass through a 200 sieve, and yet all be

collected on a 250 sieve, if we had one that fine, in which event, the cement would be economically useless, as it would take too long to harden. There would be no impalpable powder.

The elutriation test (suspension in air.) is the only one method which will determine the amount of flour present.

Vulcanite contains more flour (impalpable powder) than other cements claiming exceptional fine grinding.

The "VULCANITE" brand has been made under one management since 1895. Only one brand is made, and the mill has been designed to accomplish the results above described.

THE following pamphlets are for gratuitous distribution, written by ALBERT MOYER, Assoc. Am. Soc. C. E.:

No. 4. Hair Cracks or Crazing on Concrete Surfaces.

No. 6. Selection and Proportion of Aggregates.

No. 7. Cement Sidewalk Paving.

No. 8. Reinforced Concrete for Houses (by Benj. A. Howes).

No. 9. Mineral Oil Mixed Concrete.

No. 10. Concrete Surface Finishes.

No. 11. Concrete in the Country (Assoc. Am. P. C. Mfgs., 112 Pages.)

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